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TRANSFERRING TECHNOLOGY TO PRIVATE INDUSTRY: DOES REALITY THREATEN EXPECTATIONS?

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Abstract

Technology has been the foundation of America's economic and military strength. Our slumping economy, stifling deficit, and growing trade imbalance reflect our declining technological performance in comparison to other nations and threaten our preeminent position of leadership in the New World Order. To stimulate technological innovation and economic growth, U.S. lawmakers directed Federal scientists to transfer technology developed within Federal laboratories to private industry. The purpose of this paper is to assess the viability of on-going technology transfer initiatives. It addresses technology transfer legislation, identifies cultural barriers to successful transfer efforts, and analyzes proposed legislation and policies regarding Federal laboratories collaborating with industry. Findings suggest Federal laboratories will not be the panacea for industry's declining competitiveness. Recommendations include formulation of a national technology policy and streamlined process for joint Government/industry technology development programs and establishment of a civilian equivalent to ARPA at a comparable funding level.

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U.S. Air Force

Faculty Research Advisor

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TRANSFERRING TECHNOLOGY TO PRIVATE INDUSTRY: DOES REALITY THREATEN EXPECTATIONS?

Technology has been key to America's military, economic and political strength, especially since the turn of the century. Industrial growth and technological prominence require a robust scientific and engineering base, a climate that encourages innovation and manufacturing excellence, the ability to efficiently commercialize new technologies into manufactured products, and a relationship between Government sponsored research and industry conducive to enhanced technological growth. These combined traits, characteristic of the American concept of progress, fueled our economic engine and enhanced our military capabilities, which contributed to the demise of the Soviet economy and brought about the conclusion of the Cold War. In today's post-Cold War era, however, the United States stands to lose influence as the New World Order takes shape, especially in the economic arena.

Although the U.S. continues to lead the world in basic research, the process of translating new ideas and concepts generated within the U.S. into marketable products needs substantial improvements if the U.S. is to improve its international competitiveness and remain the recognized leader in scientific and engineering research and development (R&D). The U.S. Government, confronted with the realities of fierce global economic competition, directed Government laboratories to transfer the results of their R&D to industry for commercialization. Government policymakers hope to utilize Federally developed technologies to stimulate industrial growth and increase individual productivity. Discussions on Government's role to improve U.S. industrial competitiveness have developed into a heated debate about a national technology policy.

The purpose of this paper is to assess the viability of current technology transfer policies, directives and programs as stimulants for increased industrial competitiveness. This paper addresses recent Congressional activities related to industrial competitiveness and technology transfer, analyzes recent technology transfer initiatives, identifies significant barriers which

preclude successful technology transfer to industry, assesses the climate on Capitol Hill regarding the future of Government R&D, and concludes with recommendations which, if adopted, will result in better utilization of Federal resources to enhance U.S. industrial competitiveness.*

PROMOTING U.S. INDUSTRIAL COMPETITIVENESS

The importance of our future technological strength, with its direct bearing on our nation's national security, only increases with time as nations of the world migrate toward increased global interdependence. Concerned with the growing strength of foreign competition and our country's deteriorating position in international markets, former Secretary of Commerce Barbara Franklin stated at a recent National Technology Initiative conference:[1]

> "The competition out there is fierce today. Today's battles are not between armies, but between economic interests of various nations. In this arena, we Americans have strong advantages. We're innovators, we're inventive, and we're risk takers. We need to build on these strengths and one place to start is by becoming better partners."

The partnership she refers to is between Government and industry, with the common goal of increasing U.S. competitiveness in the world marketplace.

With diminished East-West tensions, North-South and domestic issues in the form of economic concerns have come to the forefront. The American public, as well as Congress, are aware of our stagnant economy, and all want to stimulate its growth. Many scholars suggest that technology is the key factor driving the evolution of global competition.[2] Japan and the European Community are now two giants in the economic arena, with whom the U.S. has to

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* The civilian sector can and should derive benefits from classified research. This paper focuses on the transfer of technology that is free to move from one sector to another without classification restrictions, with discussions directed at R&D activities considered unclassified by the Federal Government.

work with to ensure regional and global political stability. And yet we must compete against them in order to maintain our traditional economic stature in the world.

Recognizing the linkage between technological preeminence and economic competitiveness, Congressperson Joan Horn made the following statement before the Subcommittee on Technology and Competitiveness:[3]

> "I can think of no more important topic in technology and competitiveness than how we can better transfer the discoveries made in our research labs to the private industry. It is vital to our future economic health. While as a nation we excel in basic sciences, we seem to be failing in reaping the economic rewards of our scientific discoveries through the production of consumer goods. We make the discoveries, someone else makes the products."

Ms. Horn also asked very pointed questions regarding the lack of success in transferring technology from the Federal laboratories and agencies to the industrial sector. She wanted to know which laboratories were successful, why some were more successful than others, and what problems needed to be addressed to transfer technology to the private sector, especially to small businesses. Congress recognizes that the U.S. Federal laboratory system is a powerful national resource for technology exploitation.

Redirecting Federally Conducted R&D

With over 720 Federal laboratories, employing more than one-sixth of U.S. scientists, and consuming nearly $20 billion per year conducting R&D, the U.S. Government's investment in R&D is unequalled.[4] Federal laboratories and research facilities contain technical capabilities unmatched anywhere in the world. Many discussions on economic competitiveness call for linking these resources more closely to industrial firms to increase industrial innovation. Many in industry and Congress hope that previously untapped Federal laboratory resources will provide the technology and impetus to stimulate U.S. industrial competitiveness. In particular, they propose that Department of Defense (DoD) and Department of Energy (DoE) laboratories offer a wealth of technical expertise which, in many cases, could be transferred to industry with significant follow-on commercial applications.

Previously concerned only with their specific missions, most Federal laboratory workers concentrated in specialized areas with little regard to spinoff technologies for commercialization. The intent of Congress is to change this perspective. In addition to specific technology transfer activities directed by Congress over the past few years, on-going hearings and proposed technology transfer legislation suggest additional requirements will soon be levied on Federal laboratories.

The Latest Guidance

Congress has legislated a number of actions to transfer technology from Federal agencies to industry. The technology innovation legislation highlights prepared by the Federal Laboratory Consortium in *Technology Innovation*[5] and the review by Higgins[6] provide essential details of directives up through 1990. Since then, there have been substantial changes which effect the process of technology transfer, especially with respect to the Department of Commerce (DoC) and DoD. In summary, they are as follows:

The Defense Authorization Act for FY 1990 [7]

- Established the National Critical Technologies Panel to develop a list of technologies critical to future U.S. national security and/or economic well being.

American Technology Preeminence Act of 1991 [8]

- Strengthens the programs and activities of DoC's Technology Administration and National Institute of Standards and Technology (NIST).
- Amends the Advanced Technology Program (ATP) by authorizing NIST to award grants and enter into contracts and cooperative agreements with U.S. businesses.
- Defines a U.S. owned company as a company that has majority ownership or control by individuals who are citizens of the U.S., and establishes guidelines on joint efforts with non-U.S. companies located in the U.S.

- Establishes a national commission on reducing capital costs for emerging technologies.
- Establishes a research, development, technology utilization, and Government procurement policy commission to analyze the effects of Federal procurement laws, procedures, and policies on the development of industrial technologies.
- Establishes the National Quality Council to formulate national goals and priorities for quality performance in business in the U.S.

National Defense Authorization Act for FY 1993 [9]

- Establishes a new chapter in Title 10 to consolidate, review, clarify and enact policies and requirements to the national technology/industrial base, and defense reinvestment and conversion programs to further national security objectives.
- Establishes the National Defense Technology and Industrial Base Council to provide overall policy guidance and ensure effective cooperation among agencies and departments in the Federal Government.
- Establishes a national defense program for analysis of technology and the industrial base.
- Establishes the Center for the Study of Defense Economic Adjustment to address issues related to the conversion and reutilization of defense personnel, resources, and facilities.
- Requires periodic national technology and industrial base defense capability assessments and capability plans.
- Provides for the establishment of defense dual-use technology partnerships, defense dual-use critical technology partnerships, and commercial military integration partnerships.
- Establishes the Office of Technology Transition and Military-Civilian Integration and Technology Transfer Advisory Board to ensure defense technology developed

is integrated into the private sector to the maximum extent possible.

- Establishes the National Defense Manufacturing Technology Program and Defense Dual-Use Assistance Program to promote dual-use technology development and further national security objectives.
- Suggests renaming the Defense Advanced Research Projects Agency to Advanced Research Project Agency to reflect increased emphasis on dual-use technologies.

Effectiveness of technology transfer legislative actions has been mixed at best. The number and diversity of actions result in conflicting guidance and confusion among both Federal and industrial laboratory managers and researchers.[10] Laboratory personnel are attempting to execute a technology transfer program while at the same time Government leaders are still mired in its conceptual phase. The de facto technology policies of the Cold War era are obsolete, but they have not yet been replaced by a cohesive strategy for the future. It is not surprising that a number of barriers remain which impede effective transfer from Federal facilities.

An Impatient Congress

Congress continues to be active in the pursuit of technology transfer to industry. In September 1992 , the House held a hearing on the National Aeronautical Research and U.S. Competitiveness Act of 1992.[11] Afterwards, a bill was introduced and referred to the Committee on Armed Services to increase cooperation between DoD research and production facilities and U.S. industry.[12] The bill, known as the Federal Defense Laboratory Diversification Program, states that DoD production and research facilities currently lack incentives to carry out cooperative development activities with private industry. In addition, industry does not have sufficient opportunity to provide input into DoD research related to dual-use technologies. The diversification program is intended to promote coordinated DoD and industry development, application and transfer of dual-use technologies for the purpose of commercialization. In addition, the bill will require development of laboratory benchmarks and

metrics to assess their transfer effectiveness. Each laboratory is expected to allocate a minimum of 2% to 5% of their budget to cooperative efforts. Each laboratory will also be required to establish an industry and academic advisory panel to oversee their research plans and the implementation of this act.

In the Senate, turf battles are raging over who is to be responsible for overseeing commercialization of Federally developed technology. Senator Hollings (D-S.C.), who is chairman of the Commerce, Science and Transportation Committee's subcommittee on commerce, introduced legislation to make DoC the lead agency for technology transfer and industrial competitiveness efforts with an expanded NIST role for future industry/Government technology development efforts. In the meantime, Senator Johnston (D-La), viceroy of the Energy Department, announced the introduction of a technology transfer bill that makes DoE's laboratories the lead agents. Senators Jeff Bingaman and Pete Domenici of New Mexico support his proposal and further state that "DoE has scientific and technical capabilities and resources within the departmental laboratories in virtually every area of importance to the economic, scientific and technological competitiveness of U.S. industry."[13] They expect at least ten percent of each Federal laboratory's budget to be reserved for cost-shared partnerships with industry.

Unfortunately, Congress is more inclined to provide long-term support for political, not technical, reasons.[14] They are quick to withdraw support from technology driven programs that have lost their political glitter. Combined strong Presidential leadership and non-partisan Congressional commitment are required to achieve a long-range technology plan and economic stability. Much has already been done in the Federal sector. What's really needed, however, is a national technology plan, one that encompasses both foreign and domestic technology transfers. It should express long term goals, state specific objectives, identify the means of achieving these objectives, and establish metrics to gauge progress. It must, to the maximum extent possible, be insulated from the influences of day-to-day politics. It needs to have vision, long-range goals and stable multi-year funding.

TECHNOLOGY TRANSFER INITIATIVES

Over the past dozen years, Federal agencies have made significant progress in efforts to transition technology developed within the Government sector to the industrial sector for subsequent development and commercialization of consumer goods and services. DoD's newly developed Science and Technology Strategy, several Federal agency initiatives resulting from President Bush's directives, and technology transfer mechanisms offer further insight into efforts to bridge the technology gap between Government and industry.

DoD Science and Technology Strategy

Maintaining technical superiority in our weaponry continues to be a key element of our national security strategy. In response to shrinking budgets and a diversification of threats, the Director of Defense Research and Engineering (DDR&E) formulated a new Science and Technology (S&T) strategy.[15] DoD's S&T experts established a framework to meet these challenges.[16] DDR&E defined seven thrusts for which advanced technology demonstration programs will be carried out to identify and prove specific capabilities toward meeting the goals of each thrust (budget category 6.3A). Technologies exploited in these demonstrations are derived from exploratory development programs (category 6.2) which consist of 11 key technology areas. These technologies are to be built upon new knowledge derived from DoD's basic research program (category 6.1). A brief discussion of each category identifies which areas offer the most likely candidates for technology transfer.

Basic Research (6.1). DoD has historically devoted approximately $1 billion each year to develop scientific knowledge under the auspices of basic research. This work is conducted in Government facilities, universities and private industry. It represents nearly 8% of total Federal research spending and 5% of total national research spending.[17] DoD basic research efforts are directed toward the following disciplines, listed in order of decreasing amounts to be expended in FY 1993: electronics, ocean science, mechanics, materials, physics, chemistry,

computer sciences, mathematics, biology and medicine, cognitive and neural science, atmosphere and space science, and terrestrial sciences. All of the work performed under budget category 6.1 is considered to be unclassified and could potentially have direct relevance to civilian applications.

Exploratory Development (6.2). As promising technological advances appear, they are selected to be studied for possible development as an advanced technology demonstration. This exploratory development program is built around 11 key technology areas.[18] They are: computers, software, sensors, communications networking, electronic devices, environmental effects, materials and processes, energy storage, propulsion and energy conversion, design automation, and human-system interfaces. Much of this work is conducted within Government laboratories, but a considerable share is contracted out to industry with some university participation. Many development spinoffs could be utilized in industry. Portions of this work may be classified, if specifically related to classified weapon system development programs. Technology applications that are successfully proven may apply to one or several of the seven thrust areas.

Advanced Development/Thrust Areas (6.3A). Most demands placed on DoD's S&T program by the users' most pressing operational requirements are captured in the seven thrusts.[19] The initial list includes: global surveillance and communications, precision strike, air superiority and defense, sea control and undersea superiority, advanced land combat, synthetic environments, and technology for affordability. The goal of the seven thrusts is to ensure the availability and integration of advanced technologies to meet crucial military capabilities. Most all of this work is contracted to industry and some is classified.

Federal Agency Initiatives

Each Federal agency which conducts R&D has a technology transfer program. A number of forums have been established to assist industry in gaining access to Federal R&D resources. These include the National Technology Transfer Center, Regional Technology

Transfer Centers, Federal Laboratory Consortium Locator Network, Federal Laboratory Consortium, and the National Technology Initiative. The first three in this list form the information network (and limited technology transfer process training) that points the interested researcher to the right Federal laboratory. The latter two warrant further discussion since they have been active forums to bring scientists and engineers from industry and Government together to disseminate information on Federal laboratory capabilities and resources.

Federal Laboratory Consortium (FLC). FLC was officially chartered by the Federal Technology Transfer Act of 1986[20] to strengthen technology-based cooperation between the Federal laboratories and U.S. businesses, universities, state and local governments, and the Federal agencies. FLC promotes the transfer of science and engineering results from Federal laboratories into applications in the private and public sectors by creating an environment conducive to technology transfer efforts. FLC focusses on national initiatives that are beyond the scope of individual laboratories and departments or agencies. They develop and test transfer methods, address barriers to the process, highlight successful efforts, provide training and emphasize national initiatives where technology transfer has a role.[21] DoD laboratory involvement has been noticeably modest in FLC activities.

National Technology Initiative (NTI). NTI was a Presidential initiative launched in early 1992 which consisted of 14 regional conferences held across the nation during the year. The principle goal of NTI was to promote U.S. technological competitiveness by increasing the effectiveness of industry/Government partnerships.[22] Each conference addressed specific, regionally-significant areas of technology and included exhibits staffed by Federal agencies, universities and laboratories.* These conferences provided a high-visibility way for Federal agencies to reach industry to inform them of what Federal technology transfer was all about and

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* A summary of the first ten conferences is presented in their October 1992 report, which also includes a synopsis of other Federal organizations geared to foster transfer of technology from the Federal sector. The first ten conferences averaged over 350 attendees with attendance increasing at successive meetings.

how industry could participate. They also addressed financing research, licensing agreements, and cooperative agreements between Government and industry. There are currently no plans to extend NTI past 1992, however. Again, DoD participation has been somewhat disappointing.

Technology Transfer Mechanisms

Several technology transfer mechanisms are available between industry and Federal laboratories. These include cost-shared contracts, joint-cooperative agreements, exchange programs, workshops and seminars, consultations, specialized license, patent and facility arrangements, and cooperative research programs. A 1992 survey of over 100 directors of 50 mid-sized and large commercial laboratories concluded that industry's greatest potential for utilizing Federally developed technology is through cooperative research programs, which includes cooperative research and development agreements (CRADAs) and R&D consortia.[23]

CRADA. A CRADA is a legal agreement which implements the new authority specified in the Federal Technology Transfer Act of 1986. CRADAs include agreements between one or more Federal laboratories and one or more non-Federal parties under which the laboratory provides personnel, services, facilities, equipment or other resources, with or without reimbursement. The non-Federal parties provide funds, personnel, services, facilities, equipment or other resources toward the conduct of specified research or development efforts which are consistent with the missions of the Federal R&D activity. The term does not include procurements, grants or other types of cooperative agreements made under the authority of any other legislation. A CRADA typically has to be renewed every year, which provides participating parties a means of terminating the agreement. CRADAs will usually be terminated if the work has been accomplished or, if any of the involved parties are not satisfied with progress or the arrangements. Industry and Federal agencies have signed 1360 CRADAs as of the end of January, 1993, with several hundred more in the negotiating phase.[24]

CRADA effectiveness is extremely difficult to determine. Successful transfer of technology should result in new marketable products, increased productivity, more patents, and

overall industrial growth. Essentially no data exists to objectively assess CRADA effectiveness. Dr. Bruce Mattson, who heads the office which works with intellectual property rights, CRADAs, licensing agreements and disclosure statements for NIST, suggested that possible interim metrics for "perceived" success of CRADAs could be the number renewed each year as well as the number of return customers. Although not a quantitative measurement of how well technology has been transferred and incorporated for commercial purposes, these metrics can be a valuable indicator. A company would most likely not renew a CRADA if their experience was bad, or if they did not derive benefits from the arrangements. As the CRADA program matures and as Government and industry gain experience with CRADAs, more definitive data will become available to assess CRADA effectiveness.

Consortia. These agreements include participation from multiple Federal and non-Federal groups working on a common R&D goal, which often requires interdisciplinary approaches. Participants are often representatives of Government, industry, and academia, blending the spectrum of activities from theoretical research to full-scale manufacturing. Consortia funding may be shared, but dependent upon the arrangements agreed to by all parties involved. To tackle the more complex interdisciplinary problems, the consortium approach offers the greatest advantages. The trend will be for greater numbers of consortia-type activities as their success and subsequent popularity increase with time. CRADAs and consortia are ideally suited to carry out the objectives of DoD's new acquisition strategy, as observed in a number of Federal organizations that maintain close relationships with industry.

Making Swords and Plowshares

Several Federal organizations are noted for their ongoing and/or recent successes in contributing useful technologies to the commercial sector. Results of interviews with representatives from the Defense Advanced Research Projects Agency (DARPA), the National Institute of Standards and Technology (NIST), and the Air Force Office of Scientific Research (AFOSR) are presented.

DARPA. DARPA's mission is to exploit high payoff, high risk technologies with an emphasis on military applications. DARPA was created in 1958 as the Advanced Research Projects Agency with the mission of pursuing basic and applied R&D to feed the military services in their pursuit of promising weapon systems.[25] DARPA, soon to be called ARPA again, strives to stimulate, develop, and demonstrate technologies which can cause fundamental changes in future military systems and operations. As stated in the 1992 Secretary of Defense report to the President and Congress, DARPA targets areas for timely transition to weapon capability through specially designed prototypes, technology demonstrations, and manufacturing processes key to fostering a robust industrial base.[26]

DARPA emphasizes dynamic technologies which are changing too rapidly for traditional research and development practices to adequately capture. Their current main thrust is in the development and exploitation of information sciences, stressing solid state microelectronics, scalable high performance computers, decision support systems, and integrated design and manufacturing. Other areas of effort are simulation, advanced materials, sensors, and manufacturing processes. An historical example of their success was the initial development of the electronic mail network that is fast becoming the world's main means of rapid and inexpensive communication.

DARPA funds research in universities (about 16% of their $1.6 billion for FY 1992), government laboratories (11%), and industry (60%), with an absolute minimum of administrative layering through a horizontal-type of organizational structure. Program managers are quite free to pursue technologies they perceive as promising, and have attained a great deal of success throughout a spectrum of activities. DARPA is also authorized to enter into contractual arrangements in which they can be full partners with industry, receiving royalties, etc. These flexibilities provide a fertile research environment conducive to creative thought, industrial collaboration and technology transfer for commercialization purposes. During the 1980s, however, DARPA was forced to tie its programs more closely to military objectives, and shift its efforts toward applied research.[27]

DARPA's strategic vision of long-term, high-risk technologies and subsequent success in developing such technologies as computing, simulation, and virtual reality have attracted the attention of industry and Federal policymakers. Congress wants to extend DARPA's charter to address technologies of commercial interest. Their budget was increased from $1.6 to $2.4 billion for FY 1993, for the pursuit of dual-use technologies. DARPA's success also influenced Congressional actions to form the Advanced Technology Program (ATP), a civilian "mini-equivalent" to DARPA, under the direction of the Commerce Department.

NIST. NIST's relationship with industry has historically been very close and promises to be even closer in the future. NIST had its beginnings back in 1901 as the National Bureau of Standards, with a charter to establish standards for industry that would ensure new and evolving products adhered to certain common conventions.[28] Hence, the gap between NIST workers and industrial researchers has been relatively narrow and the cultural barriers which confront personnel from NIST are not as great as those facing several other Federal agencies. The Omnibus Trade and Competitiveness Act of 1988 further expanded NIST's role in the transition of technology into the private sector.[29] One would expect, therefore, significant gains could be made in developing successful technology transition efforts between NIST and industry, provided NIST's approach is sufficiently proactive. That is exactly what has occurred.

One of NIST's first steps was to enter into CRADAs with organizations from the private sector.[30] NIST's success in overcoming cultural barriers is demonstrated in the growth of their CRADA program, as shown in the table on NIST CRADA activity for the last 5 years.[31]

CRADA Activity for NIST (1988-1992)

Fiscal Year	1988	1989	1990	1991	1992
Newly Signed	5	37	40	62	82
Total Active	5	42	80	110	168

The figures above indicate a notable growth in the number of new CRADAs each year as well as a substantial increase in the number of active CRADAs, which at least signifies early-on "satisfaction" of the customer.

Dr. Mattson attributed their success to a number of items. Among these are:

- Culture in working with civilian institutions has historically been good.
- By the very nature of work performed, little, if any, is classified.
- Lean and mean process was developed and instituted to handle agreements.
  -- On the average, it takes only 8 weeks to get CRADAs signed at NIST.
  -- Only three signatures are required to implement a CRADA.
  -- Legal personnel work directly with and among the scientists.
  -- The key is delegation of authority to work out agreements.
  -- Scientists fill out the simple and easy to read CRADA form.
- 30% of any invention royalties go to the scientist.
- Performance appraisals require participation in joint ventures.
- Guest researchers are invited into NIST to work with NIST scientists.

Dr. Mattson also indicated that the trend is for more consortia, which requires at least two partners from outside of NIST. Of the 1992 CRADAs, 54% consisted of multi-industry consortia. A detailed description of the NIST technology transfer program is highlighted in the February 1992 issue of *Cooperative Technology RD&D Report*.[32]

AFOSR. Under the Directorship of Dr. Helwig, AFOSR is committed to transferring technology to the industrial sector. AFOSR's mission is to fund and manage Air Force research activities (mostly 6.1 with some 6.2) conducted within academic institutions, private industry, and Air Force laboratories. AFOSR's major R&D objective is to provide the necessary basic research for its primary customers, the Air Force laboratories. AFOSR is currently assisting these laboratories to define and structure their technology transfer programs. To maximize technological information exchange, AFOSR manages a number of programs which have a

"people" focus.[33] Three of these programs are designed to enhance both collaborative research efforts and communications among professional scientists and engineers with the use of temporary duty assignments. The Window on Science program brings foreign scientists to the U.S. to contribute to and participate in primarily Air Force sponsored research projects. In other "Window" programs, Air Force scientists conduct research for up to 179 days in other laboratories at locations in Europe and the U.S. AFOSR also sponsors a number of graduate and post-graduate fellowships to provide communications and increased understanding among a broad spectrum of research establishments. These exchange programs have resulted in a number of contracts and grants, with primary benefits going to Federal laboratories. The resulting cooperative R&D efforts, however, will be beneficial to both sectors, especially in the long-term.

AFOSR is working with Air Force Materiel Command to develop a new regulation on the conduct of Independent Research and Development (IR&D) programs within industry. A portion of the funding on Air Force development contracts is marked for contractor directed IR&D. Historically, IR&D efforts were reviewed by Air Force researchers and evaluated as to applicability to Air Force R&D interests. With the recent emphasis on dual-use technologies and commercialization of DoD sponsored research, the contractor is no longer required to spend IR&D funds on Air Force directed problems. This change in philosophy presents an ideal opportunity for Air Force researchers to interact and collaborate with their industrial counterparts on commercialization of DoD developed and sponsored research. Hence a new regulation covering Air Force sponsored IR&D efforts is required. In addition, Army and Air Force efforts are underway to revise AR 70-57 and AFR 80-27, which provide guidance for each service's technology transfer programs.

AFOSR works with the Army Research Office and the Office of Naval Research to coordinate their research activities. All three of these organizations perform a similar type function within their respective services. Their mode of operation and proactive activities with industry and universities provide a military example for Government laboratories to look into.

BARRIERS IMPEDE TECHNOLOGY TRANSFER

A number of impediments restrict the transfer of technology from Government to industry and/or universities. Some impediments also constitute barriers to technology flow in the opposite direction. Existing cultural differences between Federal and non-Federal technical personnel, perceived and actual bureaucracy, and conflicting policies are found to significantly restrict the diffusion of technology sought by Congressional leaders.

Cultural Differences Between Federal and Non-Federal Researchers

There exists a large disparity between researchers in Federal laboratories and private institutions. A number of differences become apparent when examining the cultures of the two sectors.

Research Aims. Government is the principle supporter of basic research and a contributor to applied research. Basic research is accomplished primarily in Government laboratories and universities, which often leads to collaboration between Government and university researchers with common interests. Industry involvement in basic research is minimal, thus Federal researchers who conduct basic research are more closely aligned with their counterparts in universities than within industry. Some applied R&D is conducted in Government laboratories, but most is performed in industry through both Government and private funding. All applied R&D funded by the Government, whether conducted in Federal facilities or in industry, is directed at satisfying Government objectives, such as weapons system development. Industrially funded applied R&D is, with few exceptions, aimed at commercialization of products and services. There has been little industrial interest in Federal R&D and minimal contact with Federal researchers, unless Government was the customer. Thus basic research brings Federal and university researchers together, while applied R&D typically drives Federal and industrial researchers apart. Pursuit of dual-use technologies will hopefully remedy this situation for the future.

Demographics and Conflicts of Interest. In an assessment of technology transfer from universities to industry, Rogers found transfers through formal agreements were fairly ineffective, unless the firms were immediate neighbors to the universities.[34] If one looks at the demographics of thriving high technology companies, the majority are small to mid-sized and are located in the vicinity of university research centers.[35] Stanford University on the outskirts of Silicon Valley provides an excellent example. Universities encourage researchers to form spinoff companies, which effects a more productive and efficient means of transferring technology. Perceived and actual conflicts of interest prevent Federal researchers from such entrepreneurial undertakings. Annual conflict of interest briefings keep Federal and industrial researchers at arm's length. Industry will allow spinoffs as long as proprietary rights are adhered to. Thus, the university, Government and industrial researcher all differ in this regard.

Time Factor. Federal research can typically take up to 10 years before satisfying objectives or reaching maturity. In contrast, industrial researchers need to successfully achieve a commercial application status in a much shorter timeframe, typically less than 2 years. Not driven to the same time constraints, Federal researchers can often tolerate higher risks in their efforts to achieve high payoffs.

Openness. Industry usually adheres to strict controlled access to research results in order to produce and market a product ahead of their competitors. Quality research in the federal sector, as with universities, often depends upon open and free communication. This fundamental difference can result in a significant barrier to technology transfer between Federal and industrial counterparts, since they do not share the same objectives.

Patent Filing. Federal researchers are usually self-driven to publish their works and/or see the results of their efforts picked up for further development for applications under Government sponsorship. There is little, if any, incentive to spend the time to file for patents and licenses. Obtaining a patent can impose limitations on communications with colleagues outside their laboratory due to restrictions generally placed on domestic and foreign patent filings to protect intellectual property claims. Delaying the publication of a paper while filing a patent,

a time consuming process, leaves the researcher turned off. From 1987 to 1991, less than 1.6% of Federal scientists reported inventions with hopes of receiving a patent.[36] There is little effort spent to train Federal scientists on the patent application process. Nor are they instructed on how to recognize patentable research efforts as candidates for commercial applications. The scientist in private industry, however, is very much invention driven with efforts directed at making a marketable product. Since the Technology Innovation Act of 1980,[37] The Government has undertaken significant efforts to transfer technology, but little has been done to train researchers on the patent process. The Federal sector still consists of professional, highly motivated researches who know and understand their missions, but they may not be fully cognizant of commercial applications of their work. Although the trend is shifting, there remains a substantial cultural barrier to overcome.

Motivation and Federal Scientists. Most Federal scientists that I have worked with are not motivated by the annual monetary rewards of a job well done, nor the minimal monies typically received from licensing their inventions. According to a recent GAO report,[38] most federally employed scientists indicated that professional peer recognition of their research accomplishments and personal pride felt when others used their inventions were more rewarding than money. The GAO surveyed scientists from laboratories of 21 federal agencies, which represented over 80% of the in-house monies spent on Federal R&D. Federal researchers usually prefer to publish their work in scientific journals and/or present their research at professional conferences instead of seeking a patent. Publications and presentations provide widespread recognition for their research accomplishments. In contrast, the industrial researcher is usually rewarded with advancement and recognition based on his/her ability to convert innovations into marketable products ahead of their competitors. Company "secrets" are tightly held to prevent premature disclosure and possible loss of potential profit.

Royalty Sharing Policies. Patents and royalty sharing have done little to change the traditional culture of the Federal research laboratory. The current amount of patent income returned to the inventor is stipulated as a minimum 15% with each agency having the option of

establishing their own scale above that. The military services returned about 28% from 1987 to 1990 while NASA returned 71% and the remaining agencies averaged about 15%.[39] No standardized formula or scale exists and no directions on use of the other monies are stipulated. Federal researchers would be more willing to file for patents if they had more say on how royalties would be utilized. An industry's policy on royalties is usually very explicit, well understood, and agreed to by all company workers.

Red Tape and Bureaucratization

In a recent survey of directors of 276 Government and 260 industrial laboratories, perceived as well as actual red tape significantly influenced technology transfer effectiveness.[40] Transfer effectiveness was measured in terms of getting other organizations to adopt technologies developed in the laboratories and on subsequent commercial impact to the company. Comparing responses from the giver and receiver indicated that transfer success of "adopted" technology was strongly related to low levels of perceived red tape, and high ratings for commercial impacts corresponded to actual low levels of red tape in acquiring project funding, low cost capital equipment, and cooperative agreements. Administration bureaucracy associated with personnel exchanges discourages participation. The Government needs to cut actual as well as perceived red tape and bureaucratization in their facilities to enhance technology diffusion.

Conflicting Policies

There is also an apparent inconsistency between Federal policy governing conflicts of interest and the encouragement of technology transfer. Conflicting policies create apprehension and insecurity toward collaboration with industry.[41] Will Federal researchers be rewarded or reprimanded if they transfer technology? Some viewed Federal technology transfer initiatives, particularly the policy to increase collaboration with industry, as the Government's way of forcing Federal researchers to obtain private sector sponsorship to replace dwindling Federal support. To maintain a critical mass of scientific knowledge and to develop commercially useful

technology, private industry may have to step in and augment Federal research programs. These perceived uncertainties envelop a mantle of skepticism over Federal research for the future.

WHAT DOES THE FUTURE HOLD IN STORE?

The Mid 1990s and Beyond

President Bill Clinton and Vice-President Al Gore have proposed the formation of an Economic Security Council to develop an economic strategy similar to the way the National Security Council developed a national security strategy to fight the Cold War.[42] They plan to shift America's focus from making armaments to fostering a number of new civilian technologies and industries.

During the Presidential campaign, Clinton and Gore stated six efforts related to technology that they planned to achieve. Clinton plans to give Gore the responsibility to develop and coordinate the administration's vision for technology (technology policy czar); devote a significant portion of the $80 billion "Rebuild America" fund toward technology development; invest in private sector-led consortia on a 50-50 fund-sharing arrangement with the Government; refocus the current $76 billion spent on R&D each year to such areas as advanced materials, information technology and new manufacturing processes; redirect a portion of defense R&D spending to non-defense spending so as to attain a 50-50 split; and double the budget of the NIST.[43] They envision the Government acting as a catalyst in encouraging the private sector to build an advanced national communications network. They anticipate such a communications infrastructure could do for individual productivity what the highway system of the 1950s did for the nation's travel and distribution system.[44]

As a peace dividend from the end of the Cold War, they plan to redirect a minimum of $30 billion over four years from the Pentagon's research budget and apply it to civilian high technology efforts such as robotics, national communications networks, smart roads, biotechnology, computer aided manufacturing, advanced composite materials, and magnetic

levitation trains. This initiative would spend the same amount as spent on Star Wars, but in less than half the time. There are both opponents and proponents of the plan.

Their plan raises a number of concerns. First, the Pentagon and Congressmen with affected constituents will not easily let nearly $8 billion per year be withdrawn from the defense research budget, which has been one of the bright spots in developing America's technology. Second, unlike entrepreneurs who risk their own money, the Government is not as frugal and new opportunities will abound for rampant Congressional pork, resulting in vast amounts of waste. Third, a 50-50 split in funding does not give majority rule to either the Government or industry. Government bureaucrats and laboratory technologists are not the experts in industrial technology requirements, and significant amounts may be lost in pursuit of unwise technologies. Fourth, cost sharing may place unbearable constraints on some industrial companies. Therefore, Government may be picking winners and losers in the commercial sector. Fifth, industries may not be willing to give up intellectual property rights if Government becomes their partner.

Other question readily surface. Who will call the shots if taxpayers are bearing the burden and the risk of technology investments? How will economic competitiveness goals be balanced with social equity goals when Government is the full partner in funding industrial initiatives?[45] How will military and other Government research needs be accomplished if the thrust for R&D is on commercial ventures? Who will define and determine the priority of R&D projects? Finally, there is no mention of organizational structure. Federal laboratories are not organized to operate in such a manner. For that matter, neither is industry. How long will it take for appropriate legislation to be enacted to allow for such efforts? Who determines the success criteria? These bold new ways of conducting Government business pose many concerns.

On the other hand, America needs proactive leadership in the development of a technology plan. The Government needs to provide more leadership and a stronger linking of economic policy, education reform and technology. John Sculley, CEO of Apple Computer Inc., believes this can happen under strong executive leadership, and he thinks Gore can provide it.[46] The Council on Competitiveness, a private group composed of heads of major companies,

kept track of the United States' standing in the world economy. They supported the proposed Clinton/Gore plan, but cautioned against viewing Federal laboratories as the answer to all of industry's competitiveness problems. They would rather close some laboratories and redirect those funds toward the proposed programs.[47] It is interesting to note that this Council was dissolved as soon as Clinton took office.

A Future Economy with Global Focus

An economy for the future is a world economy that will consist of transnational corporations.[48] Transnationals have a global vision and orientation that transcends the definition of national identity. National wealth will be increasingly based on brainpower and a supporting social and material infrastructure, according to Robert Reich.[49] He states, "The highest earnings in most worldwide industries are to be found in locations where specialized knowledge is brought to bear on problems whose solutions define new horizons of possibilities." After closely studying high-value businesses throughout the world, he observes three different but related skills that these businesses provide. They are problem solving, problem identifying, and strategic broker skills.

Skills and Services. Problem solving skills are required to integrate or assemble things in a new way to address a need. Problem identifying skills are needed to help customers understand their needs and envision new problems, or markets, to satisfy. Strategic brokers bring their understandings of technical expertise and potential markets to link problem solvers and problem identifiers, and make a business match happen. Reich concludes that a technologically sophisticated nation's key exports are increasingly becoming the skills involved in solving, identifying, and brokering new problems. Such services are exactly what high value enterprises provide, as opposed to mass-produced consumer goods. Federal laboratories do not, in general, focus their efforts on developing such services.

Entrepreneurship. Profits of high value businesses rely on successful and ongoing discovery of connections between the solutions to problems and the identification of new needs.

This model can be applied to the problem facing our nation's economy and our efforts to transfer technology from the Government to industry. Federal laboratory personnel provide specialized research, engineering and know-how to solve many military problems. Spinoffs to non-military problems are possible, however. Industry provides design, production, marketing, and consulting services to identify problems and potential markets. What is missing is the strategic broker who provides the required services to successfully unite the two.

Brokering Technology, or Selling Real Estate. A parallel can be drawn with the real estate business. A successful real estate agent is an expert in the demographics of a particular area, utilizes an extensive network to distribute and gather information, maintains a pulse on the current and future markets, and services both the buyer and seller for a prescribed fee contingent on a successful transaction. Many use an agent as a broker to make the process as productive (and painless) as possible. Some successfully function as their own broker. Although lacking the support of the formal infrastructure available to the real estate broker, they usually utilize an ad hoc information network to solicit their customers. They must possess an understanding of the applicable legal and financial processes, however. This process becomes much more complicated in a global economy with international laws coming into play.

Insufficient Training. With implementation of technology transfer legislation, the Government has essentially declared all scientists and their management as de facto brokers. They all have the responsibility to initiate and successfully transfer any and all technology that may be of interest to the industrial sector. Without understanding the legal, technical, and financial implications, most Government personnel have been hesitant to jump into this arena. The incentive "by directive" does not provide the necessary training to perform the broker service, nor can the cultural differences be easily overcome.

Sell-Tech, Inc. Establishing a program whereby a high value enterprise could perform the technology transfer broker function would increase the efficiency of the transfer process. The "Sell-Tech" company[50] would be profit motivated, receive its brokerage commission from industry for successful transfers, and be made up of personnel knowledgeable about CRADAs,

patents, licensing agreements, disclosure statements, current legislation, and technical capabilities and opportunities between Government laboratories and industry.[51] Federal regulations would be required to govern the conduct of such brokerage firms.

As a step in this direction, the University of Chicago created ARCH in 1986 as an intermediating organization to commercialize innovations generated between the university and Argonne National Laboratory.[52] ARCH does not shape or direct the work of individual researchers, but it evaluates and selects those programs that have the greatest commercial application potential and channels the results toward the marketplace. Thus, licensing and small company formation are linked, which is an efficient means of transferring technology into industry and generating economic wealth.

As an international example, Gansler reported that the government of the United Kingdom utilized private venture capital to establish the firm, Defense Technology Enterprises, Ltd., for the sole purpose of transferring military technology to civilian industry.[53] Many of its employees are located within the Ministry of Defense laboratories to identify technologies that can be used in the civilian sector. Even classified work is reviewed for potential declassification and use in industry. Other countries emulate this type of arrangement to utilize government developed dual-use technologies. With cultural differences in mind, one should carefully review the industrial policies of foreign countries in order to benefit from their experiences.

An Added Dimension-Foreign Contributions

The disappearing distinction between military and civilian technology has also led to a defense industrial base that is no longer national, but international. To ensure the best performance for upgraded and next generation weapon systems, military weapon system developers need to take advantage of civilian developed technologies, such as those in electronics. In many cases, the best technology is developed by firms outside U.S. borders. In addition, the relationship between government and industry in the U.S. is different from that in most foreign countries. These differences pose challenges as U.S. industries have to compete

with foreign governments as partners with foreign industries. Since the U.S. has been losing marketshare to foreign competition, we should recognize our reliance on and the contributions of foreign advances in technology. Although not within the scope of this study, a look at the European Community and Japan is warranted if we are to learn from their success, and especially if our dependence on foreign contributions increases in the future.

Working Together

William Ouchi spent years studying major corporations in Japan and the U.S. In his book *Theory Z*, he identified a culture common among successful Japanese firms.[54] This "Theory Z" culture has distinct values, which include trust, intimacy and subtlety. Intimacy and subtlety are synonymous with close personal relationships among workers and a spirit of cooperation within the workforce. Managers instill this culture among the workers, which results in cohesive organizations working together. He emphasizes the importance of directing attention to human relations both in and out of the workplace to maintain this culture, which also gives rise to high individual productivity and increased profits for the firm.

From Ouchi's discussions, it follows that the corporate culture in Japanese firms is not unique to Japan, but is also found in some U.S. firms. In addition, increased productivity is a direct result of working together. These lessons should provide encouragement to Government leaders and industrial managers as they attempt to modify the existing cultures between laboratories and encourage scientists to work together to transfer technologies.

Research capabilities that currently exist in Federal laboratories may indeed have the potential to provide the technical edge that U.S. industries need to remain competitive in the domestic and international markets. Cooperation is the key if this potential is to be transformed into tangible results. The first step is to ensure Government research efforts are focused under a coherent plan. As a step in that direction, in the absence of a national technology plan, DoD recently initiated a program called "Project Reliance" aimed at improving the coordination between the services.[55] Sixteen tri-service panels were formed to oversee the joint planning

and research efforts which engulf the services' category 6.2 and 6.3A programs. The effort is specifically intended to reduce unwarranted duplication of effort, consolidate some efforts to ensure a "critical mass" is established and maintained, and conduct joint planning and execution of research and development programs. Project Reliance is geared towards applied research rather than basic research. Involvement of other Government agencies and industry in this project could be advantageous in these economically difficult times.

An example of DoD and industrial cooperation is the Integrated High Performance Turbine Engine Technology (IHPTET) program. Formulated by DoD, it was planned by a consortium including the Army, Navy, Air Force, DARPA, NASA, and seven turbine manufacturers from industry. With the government encouraging pre-competitive technology cooperation, the seven companies formed a consortium to pursue the development of fibers for advanced composite materials.[56] Both NASA[57] and Pratt & Whitney[58] testified before the House Subcommittee on Technology and Competitiveness that IHPTET was a model program for cooperation between the Government and industry.

SUMMARY AND RECOMMENDATIONS

In summary, hopes and expectations for near-term gains in industrial competitiveness by transferring Federally developed technologies will not be realized. It is recognized that the future economic well-being and national security of the United States are based on our ability to compete successfully in industry. The strength of our industry is in turn based on technological competitiveness, from basic research through manufacturing to marketing. Many reports and testimonies before Congress call for a closer linkage between Federal laboratories and industrial firms to increase Government contributions to industrial innovation. Too much dependence is being placed on technology transfer from Federal laboratories, however, and not enough on collaboration between firms and innovation within firms. Federally developed technology may contribute to industrial competitiveness under limited circumstances, but it is

not the panacea of industry's competitiveness problems. Emerging efforts by the Government to collaborate with firms in critical R&D areas, to share funding of generic and breakthrough technologies, and to encourage cooperative research ventures between firms do hold promise for the future.

Successful technology transfer between organizations depends upon achieving a compatible match between the technology producer and the intended user. Significant cultural differences exist between Federal and industrial researchers which prevent successful matchups, and thus preclude the effective transfer of technology. Changes in culture are evolutionary and will take time to evolve. Conflicting Congressional guidance only exacerbates the problems encountered in attempts to transfer technology. Thus short-term benefits from recent transfer efforts will be limited while some long-term gains will result from the relationships being built during cooperative research efforts. Industry, as the generator of our Nation's wealth, must devise more efficient approaches to managing assets, stimulating creativity, and expediting innovation into the marketplace. Exploiting Federally developed technology is only a small part of what is required.

To help regain our technology lead, or at least maintain our status, and increase our economic competitiveness for the future, immediate actions are required. There are a number of proposed recommendations which the U.S. Government should pursue.

First. The Government must develop a well thought out, over-arching national technology policy and implement a complimentary technology plan. It should contain such elements as R&D metrics, Government and industry relationships, a long term funding strategy, critical thrust areas for concentrated efforts, an integrated DoD and other Government agency R&D effort with a forum to prioritize R&D efforts, and considerations for foreign technology development and transfer policies. The plan must require proactive participation from all levels within the Federal sector as well as key representatives from industry.

Second. The Government must develop reciprocal policies and agreements for foreign technology transfer. By reducing barriers, we can take advantage of generic and even some

applied research developed outside of our borders. Cooperative agreements should be made with foreign firms and governments to facilitate the transfusion of pre-competitive technologies. For efficiency, the U.S. should promote global R&D productivity and then follow the symbionic competition rule[59] (shake hands among friendly competing companies in the pre-competitive phase, but stop as soon as one company starts to invest in market development) to take advantage of limited domestic and foreign R&D resources, develop better generic technologies for all, and meet the demands of world markets. U.S. industry must gear up to operate in this global environment.

Third. Establish a joint industry/university/Government forum to help set Government R&D priorities and delineate Federal roles and responsibilities related to dual-use technologies. Industry and universities should be partners in the establishment and implementation of technology programs, rather than just a customer of Federally developed technology. The Government needs to consolidate and reprioritize R&D and the value it places on technology, to force a long-term perspective. Concerted efforts should be focussed to pursue generic pre-competitive research of long interest to America and American industry. Centers of excellence should be identified among the Federal laboratories as a whole to prevent duplication and to ensure a critical mass is maintained in essential research areas. A restructuring of the Federal laboratory system is in order. Elimination of excessive duplication may provide an opportunity to downsize the laboratory structure for increased efficiency.

Fourth. Promote critical Government and industrial R&D through more efficient and practical cost sharing arrangements. The Government should exploit the advantages of groups that direct research, such as DARPA for DoD and ATP for DoC. The recently established ATP should be expanded with substantially increased levels of funding to foster generic and initial stages of applied research. Small business firms should be targeted for cooperative arrangements and cost sharing to encourage spinoffs from industry, universities, and Government laboratories. Such relationships will effect more efficient transfers of technologies.

Fifth. Maintain the current level of R&D spending in the U.S. as an investment for the future. Federal laboratories should strive for dual-use technologies, where appropriate, but not at the expense of required DoD and space research efforts needed to maintain technological superiority. In this time of a somewhat stagnant economy, investment in the future is the wisest step in the long term. During a slow economic period, Government must resist the temptation to cut back R&D. Instead, Government should provide tax incentives to encourage long-term R&D investments within industry.

Sixth. Provide the opportunity for each Government agency to establish the framework for "Sell-Tech" type companies to broker the transfer of technology to the private sector. Sell-Tech earnings would primarily result from fees paid by the gaining company. Also, encourage each agency to decentralize execution of the transfer process to the maximum extent possible.

Seventh. Reduce the red tape for industries to enter into cooperative agreements with Government agencies. Industry and Government collaboration should be encouraged with substantial efforts to reduce both perceived and actual bureaucratic red tape associated with technology transfer. Agencies should streamline their agreement processes, decentralize execution, and simplify agreements for ease of execution. The NIST CRADA process could be considered as a model for use by DoD and other Government agencies.

Eighth. Train Federal workers to more readily recognize patentable innovations and to execute patent application procedures. The Government should review the U.S. patent system for compatibility with those in other countries. This may be an agenda for future GATT discussions in which all countries strive for a common definition and process for protecting inventions and intellectual property rights.

Ninth. Congress must commit to more multi-year R&D efforts as opposed to single year cycle renewals to ensure participating industry and Government laboratories are able to maintain stability in their R&D programs.

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